CPEN213 project:

Automatic Tank

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Presented to:

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A report for CPEN213: Microprocessors Lab

7 – 5 – 2023

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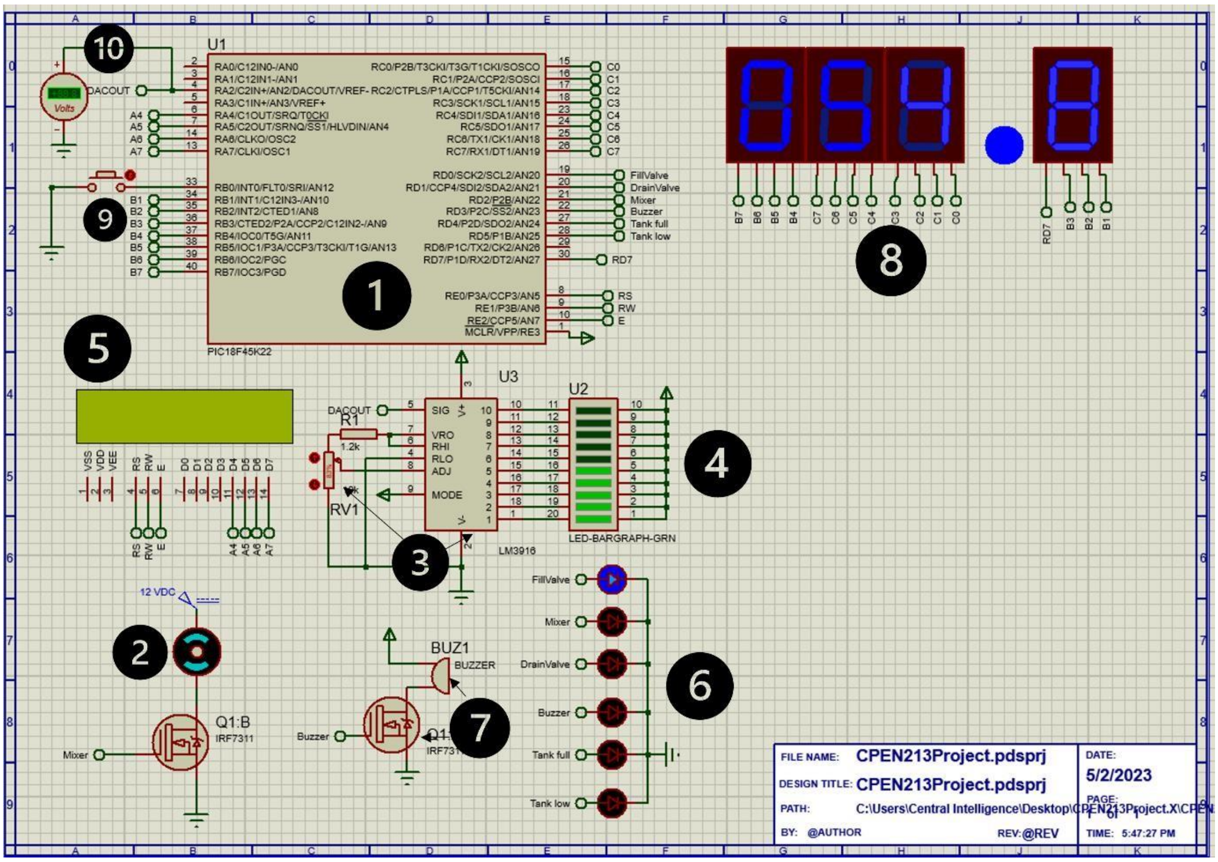
Introduction:

In this project, we are asked to design a component/schematic that imitates a tank filling process. The component takes care about filling and draining the tank by controlling/energizing and de-energizing the Fill and Drain solenoid. It should also take care about the mixing state where it controls a motor that mixes the contents in the tank for 20 seconds. After the tank is filled up, its liquid content is mixed then drained.

System description:



Many components were used in order to simulate this tank filling process and to try and show the user a tank that is filling and emptying, a motor that is working and mixing, a timer that is counting down, a display that is giving updates on the states and timer and the percentage of the tank.

1- PIC18F45K22: This microcontroller was used due to its various features such as being able to perform various kinds of operations and being able to connect and communicate directly with PIO's.

2- MOTOR: The motor is responsible for mixing the liquid. It will only turn on in the mix state.

3- LM3916: The purpose of using this component is to feed it the analog voltage output from the PIC and to control the LED-BAR-GRAPH and fill it depending on the input.

RESISTORS: 1 resistor and 1 potentiometer (POT -HG) in order to make a voltage divider circuit for the LM3916 to be able to calibrate it properly.

4- LED-BARGRAPH-GRN: The purpose of this component is to display the approximated liquid level using a bar graph. It is controlled by the LM3916.

5- LM016L: The LCD's purpose is to display information concerning the current state and the condition of the solenoids, and mixer and it displays also the time left for the mixing state to end.

6- LED-GREEN-RED-ORANGE: Each one of these LEDs (6 LEDS) is connected to these outputs: Fillvalve, Mixer, Drainvalve, Buzzer, Tankfull, Tanklow. If the LCD screen goes down for any reason the system will still contain LEDs indicators so that the user could recognize precisely the current performed state (fill/mix/drain) and the state of the tanks (filled/empty).

7- BUZZER: The purpose of the buzzer is to buzz for 3 seconds after each step is done.

8- IRF7311: 2 MOSFETS were used in order to connect the MOTOR and BUZZER to ground. When connected they turn on. The Buzzer and Mixer output from the microcontroller controls them.

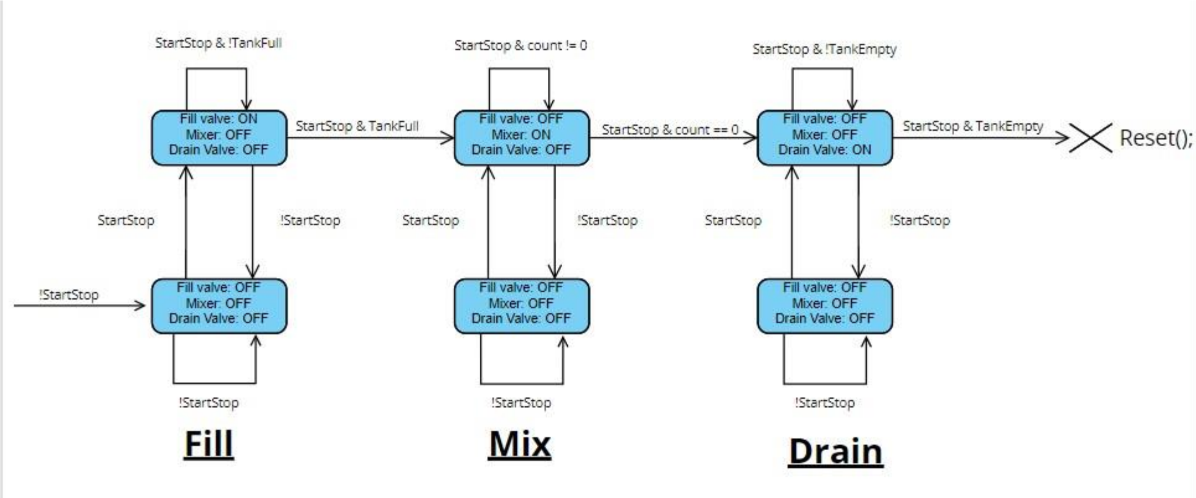
7-SEG-BCD-BLUE: Four SSG displays were used in order to display the percentage of the tank's capacity at 1 decimal point precision.

9- SW-SPST: The purpose of this push button is to be pressed in order to start or stop the process. When pressed it grounds RB0 triggering the INT0F flag and enabling it.

10- Voltmeter: This voltmeter is used in order to monitor the output from the DAC. The purpose is to show the user how the tank level is increasing and decreasing.

Software Implementation:

State machine diagram:



The actual state machine is Mealy, but for the sake of readability and ease of understanding, this state diagram is presented as a Moore state machine. (Note: Once the Mixer is OFF the counter is also OFF).

Schematic and C language program:

We declared multiple outputs and one input using the TRIS register so that we intercept data from the inputs and exchange data with outputs.

PIO:

Outputs:

1- PortB[7..1] , PortC[7..0] , PortD[7] : Used to transmit the BCD number properly to the SSG that displays the liquid percentage in the tank.
2- PortA[2] : Used as DAC output to stimulate the automatic filling and emptying of the water tank. It is connected directly to the LM3916 that represents the percentage using a graph bar.
3- PortA[7..5], PortE[2..0] : Used to power and transmit data to the LCD screen serially.
4- PortD[5..0] : Used to power the LEDs to indicate the current operations state and the tank state.

Input:

1- PortB[0] : It registers the pushbutton press that starts and stops the Machine.

Functions:

- void setup(void)**:** This method is called immediately at the start of the program in the **void main(void)** function. It is responsible for configuring the internal clock, the DAC, the timer interrupt, the button interrupt with their corresponding local and global masks, the initial states of the connected components and the outputs and inputs configurations.

- void main(void)**:** This method is responsible for altering between different states (Fill/Mix/Drain).

  1. Fill State: In this state, the **FillValve** is turned on if the user presses **Start/Stop** push-button and off if he presses it again. The LCD display the current state and the status of the valve. If the "**TankFull**" sensor is asserted the state switches to Mix, the valve is turned off, the LCD screen displays the next state, and the time count is set to 20s which represents the mixing period.
  2. Mix State: In this state, the mixer is turned on. The LCD displays the current state with the time left for the mixing to end. Anytime the **Start/Stop** push-button is pressed the state of the mixer component is switched (on/off). When the count finishes the mixer is turned off and a beeping sound goes on. Then the state switches to the Drain state.
  3. Drain State: In this state, the **DrainValve** is turned on. The LCD display the current state and the status of the valve. Anytime the **Start/Stop** push-button is pressed the state of the valve component is switched (on/off). If the "**TankEmpty**" sensor is asserted the **DrainValve** is turned, the LCD screen displays the valve state and declares the end of the operations. Then beeper goes on and then the program resets to the original state (Fill State).

- void ISR(void): This method handles all of the interrupts**.**

  1. INT0IF Interrupts: This interrupt has a higher priority than the timer interrupt. It is responsible on capturing the Start/Stop push-button press and altering the

StartStop flag. (Note: Once the INT0IF flag is captured, the register is cleared immediately).

2. TMR0F Interrupts: This interrupt is responsible on incrementing and decrementing the value of DACR, which affects the output voltage of the DAC. It is also responsible for the countdown of the timer in the “Mix” state. Lastly, it takes care in updating the percentage of the tank which is displayed on the seven sigma displays, “**TankFull**”, and “**TankEmpty**” sensors. The interrupt occurs when the TMR0 timer register overflows from its maximum value 65535 to zero. (Note: Once the TMR0IF flag is captured, the register is cleared immediately. The high byte value is written to TMR0H first, followed by the low byte value to TMR0L).

- void Beep(void): This method is responsible for turning on the buzzer for 3 seconds at the end of each state (Fill/Mix/Drain).

Conclusion:

In conclusion, this project allowed us to program the PIC18F45K22 in order to stimulate a real pump by sending an analog signal from the DAC to fill and empty the tank automatically. In addition, it enables the user to identify precisely using the screen and LED’s the current state of the operations (fill/drain/mix) and of the tank (filled/empty). The user could also recognize the exact percentage of the tank at one decimal point precision using a seven-segment display. The design is able to transition seamlessly between different states using sensors that detect the tank liquid level. In the future, we may use a multiplexed display in order to use much less ports and save them for other uses. Moreover, a good upgrade would be to add a graphical user interface application (GUI) so that the user can interact directly with the hardware using a touch screen or an application. Even more, we can add some safety measures such as adding a temperature sensor to track the heat emitted from the system in such a way that if it overheats the system will shut down immediately. Overall, this experiment provided an excellent opportunity to develop a practical understanding of microcontroller programming and the PIC18F45K22 capabilities.

Appendix

C language program:

```
#include <p18cxxx.h>
#include <delays.h>
#include <LCD4PICPROTOv1.h>
#include "BCDlib.h"

#pragma     config      PBADEN = OFF        // Port B AD enable off
#pragma     config      FOSC = INTIO67      // Oscillator Selection bits (Internal oscillator block)

#define     StartStop   FLAGS.B0            // StartStop = 1/0 (start/stop)
#define     FillValve   LATDbits.LATD0
#define     DrainValve  LATDbits.LATD1
#define     Mixer       LATDbits.LATD2
#define     Buzzer      LATDbits.LATD3
#define     TankFull    LATDbits.LATD4
#define     TankEmpty   LATDbits.LATD5


enum {OFF, ON};
enum {Fill, Mix, Drain} State = Fill;
volatile unsigned char count = 0;           //counter for mix state
volatile unsigned int percentage = 0;       //Approx percentage
volatile unsigned char Digits[5];           //Used for LCD and SSD

void setup(void);
void ISR(void);
void Beep(void);



void main(void) {
    setup();
    while (1) {
        switch (State) {
            case Fill:
                if (StartStop) {
                    FillValve = ON;
                    DispRomStr(Ln1Ch0, (ROM *) "State: Fill     ");
                    DispRomStr(Ln2Ch0, (ROM *) "Fill Valve:   ON");

                    //When tank fills up, DAC is at max value, change state
                    if(TankFull){
                        State = Mix;
                        FillValve = OFF;
                        DispRomStr(Ln1Ch0, (ROM *) "Next State: Mix ");
                        DispRomStr(Ln2Ch0, (ROM *) "Fill Valve:   OFF");
                        Beep();         //Beep for 3 seconds
```

```
                count = 20;     //Timer = 20 seconds
            }

        }
        else {
            //User stops process, close fill valve, change LCD output
            FillValve = OFF;
            DispRomStr(Ln2Ch0, (ROM *) "Fill Valve:   OFF");
        }
        break;

    case Mix:
        DispRomStr(Ln1Ch0, (ROM *) "Mix is: ON       ");
        DispRomStr(Ln2Ch0, (ROM *) "Time left:     s");
        Mixer = ON;

        //count variable decrements every 1 sec based on timer0
        for( ;count != 0; ){

            while(!StartStop) Mixer = OFF; //PB pressed, stop the mixer
            Mixer = ON;
            //Display counter on LCD
            Bin2Asc(count,Digits);
            DispVarStr(Digits, Ln2Ch11, 4);
        }
        Mixer = OFF;
        DispRomStr(Ln1Ch0, (ROM *) "Next State:Drain");
        DispRomStr(Ln2Ch0, (ROM *) "Mix is: OFF     ");

        Beep();         //Beep for 3 seconds
        State = Drain;  //Mix is finished, now we drain the tank
        break;

    case Drain:
        if (StartStop) {
            DrainValve = ON;
            DispRomStr(Ln1Ch0, (ROM *) "State: Drain     ");
            DispRomStr(Ln2Ch0, (ROM *) "Drain Valve: ON ");

            //When tank is empty, DAC is at min value, reset program
            if(TankEmpty){
                DrainValve = OFF;
                DispRomStr(Ln1Ch0, (ROM *) "Program Ending!!");
                DispRomStr(Ln2Ch0, (ROM *) "Drain Valve: OFF");
                Beep();         //Beep for 3 seconds
                Reset();
```

```
                    }
                }
                else {
                    //User stops process, close drain valve, change LCD output
                    DrainValve = OFF;
                    DispRomStr(Ln2Ch0, (ROM *) "Drain Valve: OFF");

                }
                break;
        }
    }

}

void setup(void) {
    OSCCON = 0b01010000;            // 4 MHz internal clk


     FillValve = DrainValve = OFF;  // valves are initially closed
    Mixer = OFF;                    // Mixer is initially turned off
    Buzzer = OFF;                   // Buzzer is initially muted

    TRISD &= 0b01000000;            // RD7, RD5 .. RD0 are outputs
    INTCON2 &= 0x0F;                // RBPU is asserted, INTx on -ve  edge
    INTCON2bits.RBPU = 0;           // RBPU is asserted
     INTCON2bits.INTEDG0 = 0;       // INT0 reacts to a falling edge

    TRISA = 0x04;                   //output port RA2
     VREFCON1bits.DACEN = 1;        //DAC enable
     VREFCON1bits.DACOE = 1;        //enable output
    VREFCON1bits.DACPSS = 0b00;     //Vsrc+ = VDD
     VREFCON1bits.DACNSS = 0;       //Vsrc- = Vss
     VREFCON1bits.DACLPS = 1;       //enable Vsrc+ and Vscr-
    VREFCON2bits.DACR = 0b00000;    //set value to 0 V
    StartStop = 0;                  // Initially machine is off

    //For LCD
    InitLCD();                      //Initialize LCD
     DispRomStr(Ln1Ch0, (ROM *) "Start/Stop Valve");     //Display on LCD
     DispRomStr(Ln2Ch0, (ROM *) "Valve is: OFF   ");     //Display on LCD

    //For port C
    TRISC = 0;                      //RC7 .. RC0 are outputs
    ANSELC = 0;                     //RC7 .. RC0 are digital

    //For port B
```

```
    TRISB = 0X01;                        //RB7 .. RB4 are outputs

     //For timer  0  interrupt
    T0CON  = 0b10010011;                 //16  bit  timer,  enabled,  prescale,  /16
    TMR0H = (65536 - 62500) / 256;       // 62500  *  16  us  =  1  s
    TMR0L = (65536 - 62500) % 256;

    INTCONbits.INT0IE  = 1;              // enable  local  interrupt  enable
    INTCONbits.TMR0IE  = 1;              // enable  local  interrupt  enable  of  timer
    INTCONbits.GIE  = 1;                 // enable  global  interrupt  enable
}

#pragma  code  ISR  =  0x0008
#pragma interrupt ISR

void ISR(void){
    if(INTCONbits.INT0IF){
        INTCONbits.INT0IF  = 0;              //Clear flag
        StartStop  =  !StartStop;
        return;
    }else  if(INTCONbits.TMR0IF){
        TMR0H  =  (65536 - 62500) / 256;  //  62500  *  16  us  =  1  s
        TMR0L  =  (65536  -  62500)  %  256;   //  62500  *  16  us  =  1  s
        INTCONbits.TMR0IF  =  0;             //Clear  flag



        if(State == Fill  &&  StartStop){
            VREFCON2bits.DACR++;                                        //Increment  output  voltage
            percentage  =  ((unsigned  int)VREFCON2bits.DACR  *  1000)  /31;  //Compute  Approx  percentage
        }else  if(StartStop  &&  State  ==  Mix){
            count--;                                                    //Decrement count every second
        }else if(StartStop  && State  ==  Drain){
            if(TankEmpty){
                count--;                                                //Decrement count every second
            }else{
                VREFCON2bits.DACR--;                                    //Decrement  output  voltage
            }
            percentage  =  ((unsigned  int)VREFCON2bits.DACR  *  1000)  /31;  //Compute  Approx  percentage
        }



        if(State  ==  Fill  ||  State  ==  Drain){
            //Print on SSD the Approx percentage
            Bin2BcdE(percentage ,Digits);
```

```
            PORTC = Digits[2] << 4 | Digits[3];                          //RC 3..0 holds 2nd digit, RC 7..4 holds the 3rd digit
            PORTB = (Digits[1] << 4) | ((Digits[4] & 0x07 ) << 1);    //RB 7..4 holds the 1st digit, RB 3 .. 1 holds 3 least significant of 1st digit
            PORTD ^= ( (Digits[4] << 4) & 0x80);                          //RD7 holds the most significant bit of the 1st digit
        }

        //Set tank full and empty sensors
        TankFull = (VREFCON2bits.DACR == 0b11111 );
        TankEmpty = (VREFCON2bits.DACR == 0b00000);
        return;
    }
}


void Beep(void) {
    Buzzer = ON;
    count = 3;
    while(count != 0); //buzzer stays on for 3 seconds
    Buzzer = OFF;
}
```

Datasheets:

Appendices:

Data sheets:

1

MICROCHIP

PIC18(L)F2X/4XK22

28/40/44-Pin, Low-Power, High-Performance Microcontrollers with XLP Technology

High-Performance RISC CPU:

- C Compiler Optimized Architecture:
  - Optional extended instruction set designed to optimize re-entrant code
- Up to 1024 Bytes Data EEPROM
- Up to 64 Kbytes Linear Program Memory Addressing
- Up to 3896 Bytes Linear Data Memory Addressing
- Up to 16 MIPS Operation
- 16-bit Wide Instructions, 8-bit Wide Data Path
- Priority Levels for Interrupts
- 31-Level, Software Accessible Hardware Stack
- 8 x 8 Single-Cycle Hardware Multiplier

Flexible Oscillator Structure:

- Precision 16 MHz Internal Oscillator Block:
  - Factory calibrated to ± 1%
  - Selectable frequencies, 31 kHz to 16 MHz
  - 64 MHz performance available using PLL – no external components required
- Four Crystal modes up to 64 MHz
- Two External Clock modes up to 64 MHz
- 4X Phase Lock Loop (PLL)
- Secondary Oscillator using Timer1 @ 32 kHz
- Fail-Safe Clock Monitor:
  - Allows for safe shutdown if peripheral clock stops
  - Two-Speed Oscillator Start-up

Analog Features:

- Analog-to-Digital Converter (ADC) module:
  - 10-bit resolution, up to 30 external channels
  - Auto-acquisition capability
  - Conversion available during Sleep
  - Fixed Voltage Reference (FVR) channel
  - Independent input multiplexing
- Analog Comparator module:
  - Two rail-to-rail analog comparators
  - Independent input multiplexing
- Digital-to-Analog Converter (DAC) module:
  - Fixed Voltage Reference (FVR) with 1.024V, 2.048V and 4.096V output levels
  - 5-bit rail-to-rail resistive DAC with positive and negative reference selection
- Charge Time Measurement Unit (CTMU) module:
  - Supports capacitive touch sensing for touch screens and capacitive switches

eXtreme Low-Power Features (XLP) (PIC18(L)F2X/4XK22):

- Sleep mode: 20 nA, typical
- Watchdog Timer: 300 nA, typical
- Timer1 Oscillator: 800 nA @ 32 kHz
- Peripheral Module Disable

Special Microcontroller Features:

- 2.3V to 5.5V Operation – PIC18FXXK22 devices
- 1.8V to 3.6V Operation – PIC18LFXXK22 devices
- Self-Programmable under Software Control
- High/Low-Voltage Detection (HLVD) module:
  - Programmable 16-Level
  - Interrupt on High/Low-Voltage Detection
- Programmable Brown-out Reset (BOR):
  - With software enable option
  - Configurable shutdown in Sleep
- Extended Watchdog Timer (WDT):
  - Programmable period from 4 ms to 131s
- In-Circuit Serial Programming™ (ICSP™):
  - Single-Supply 3V
- In-Circuit Debug (ICD)

Peripheral Highlights:

- Up to 35 I/O Pins plus 1 Input-Only Pin:
  - High-Current Sink/Source 25 mA/25 mA
  - Three programmable external interrupts
  - Four programmable interrupt-on-change
  - Nine programmable weak pull-ups
  - Programmable slew rate
- SR Latch:
  - Multiple Set/Reset input options
- Two Capture/Compare/PWM (CCP) modules
- Three Enhanced CCP (ECCP) modules:
  - One, two or four PWM outputs
  - Selectable polarity
  - Programmable dead time
  - Auto-Shutdown and Auto-Restart
  - PWM steering
- Two Master Synchronous Serial Port (MSSP) modules:
  - 3-wire SPI (supports all 4 modes)
  - I^2C Master and Slave modes with address mask

PIC18(L)F2X/4XK22

- Two Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) modules:
  - Supports RS-485, RS-232 and LIN
  - RS-232 operation using internal oscillator
  - Auto-Wake-up on Break
  - Auto-Baud Detect

TABLE 1: PIC18(L)F2X/4XK22 FAMILY TYPES

Device	Program Memory		Data Memory		I/O[(1)]	10-bit A/D Channels[(2)]	CCP	ECCP (Full-Bridge)	ECCP (Half-Bridge)	MSSP		EUSART	Comparator	CTMU	BOR/LVD	SR Latch	8-bit Timer	16-bit Timer
	Flash (Bytes)	# Single-Word Instructions	SRAM (Bytes)	EEPROM (Bytes)						SPI	I^2C							
PIC18(L)F23K22	8K	4096	512	256	25	19	2	1	2	2	2	2	2	Y	Y	Y	3	4
PIC18(L)F24K22	16K	8192	768	256	25	19	2	1	2	2	2	2	2	Y	Y	Y	3	4
PIC18(L)F25K22	32K	16384	1536	256	25	19	2	1	2	2	2	2	2	Y	Y	Y	3	4
PIC18(L)F26K22	64k	32768	3896	1024	25	19	2	1	2	2	2	2	2	Y	Y	Y	3	4
PIC18(L)F43K22	8K	4096	512	256	36	30	2	2	1	2	2	2	2	Y	Y	Y	3	4
PIC18(L)F44K22	16K	8192	768	256	36	30	2	2	1	2	2	2	2	Y	Y	Y	3	4
PIC18(L)F45K22	32K	16384	1536	256	36	30	2	2	1	2	2	2	2	Y	Y	Y	3	4
PIC18(L)F46K22	64k	32768	3896	1024	36	30	2	2	1	2	2	2	2	Y	Y	Y	3	4

Note 1: One pin is input only.

2: Channel count includes internal FVR and DAC channels.

FIGURE 1: 28-PIN PDIP, SOIC, SSOP DIAGRAM

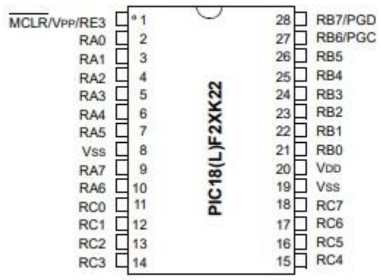
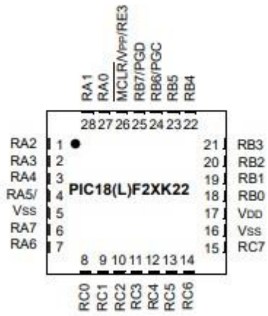


FIGURE 2: 28-PIN QFN, UQFN(1) DIAGRAM



Note 1: The 28-pin UQFN package is available only for PIC18(L)F23K22 and PIC18(L)F24K22.

PIC18(L)F2X/4XK22

TABLE 2: PIC18(L)F2XK22 PIN SUMMARY

28-SSOP, SOIC 28-SPDIP	28-QFN, UQFN	I/O	Analog	Comparator	CTMU	SR Latch	Reference	(E)CCP	EUSART	MSSP	Timers	Interrupts	Pull-up	Basic
2	27	RA0	AN0	C12IN0-										
3	28	RA1	AN1	C12IN1-										
4	1	RA2	AN2	C2IN+			VREF- DACOUT							
5	2	RA3	AN3	C1IN+			VREF+							
6	3	RA4		C1OUT		SRQ		CCP5			T0CKI			
7	4	RA5	AN4	C2OUT		SRNQ	HLVDIN			$\overline{SS}$1				
10	7	RA6												OSC2 CLKO
9	6	RA7												OSC1 CLKI
21	18	RB0	AN12			SRI		CCP4 FLT0		$\overline{SS}$2		INT0	Y	
22	19	RB1	AN10	C12IN3-				P1C		SCK2 SCL2		INT1	Y	
23	20	RB2	AN8		CTED1			P1B		SDI2 SDA2		INT2	Y	
24	21	RB3	AN9	C12IN2-	CTED2			CCP2 P2A(1)		SDO2			Y	
25	22	RB4	AN11					P1D			T5G	IOC	Y	
26	23	RB5	AN13					CCP3 P3A(4) P2B(3)			T1G T3CKI(2)	IOC	Y	
27	24	RB6							TX2/CK2			IOC	Y	PGC
28	25	RB7							RX2/DT2			IOC	Y	PGD
11	8	RC0						P2B(3)			SOSCO T1CKI T3CKI(2) T3G			
12	9	RC1						CCP2 P2A(1)			SOSCI			
13	10	RC2	AN14		CTPLS			CCP1 P1A			T5CKI			
14	11	RC3	AN15							SCK1 SCL1				
15	12	RC4	AN16							SDI1 SDA1				
16	13	RC5	AN17							SDO1				
17	14	RC6	AN18					CCP3 P3A(4)	TX1/CK1					
18	15	RC7	AN19					P3B	RX1/DT1					
1	26	RE3												$\overline{MCLR}$ VPP
8, 19 19	5, 16 16	VSS												VSS
20	17	VDD												VDD

Note 1: CCP2/P2A multiplexed in fuses.
2: T3CKI multiplexed in fuses.
3: P2B multiplexed in fuses.
4: CCP3/P3A multiplexed in fuses.

TABLE 3: PIC18(L)F4XK22 PIN SUMMARY

40-PDIP	40-UQFN	44-TQFP	44-QFN	I/O	Analog	Comparator	CTMU	SR Latch	Reference	(E)CCP	EUSART	MSSP	Timers	Interrupts	Pull-up	Basic
2	17	19	19	RA0	AN0	C12IN0-										
3	18	20	20	RA1	AN1	C12IN1-										
4	19	21	21	RA2	AN2	C2IN+			VREF- DACOUT							
5	20	22	22	RA3	AN3	C1IN+			VREF+							
6	21	23	23	RA4		C1OUT		SRQ					T0CKI			
7	22	24	24	RA5	AN4	C2OUT		SRNQ	HLVDIN			$\overline{SS1}$				
14	29	31	33	RA6												OSC2 CLKO
13	28	30	32	RA7												OSC1 CLKI
33	8	8	9	RB0	AN12			SRI		FLT0				INT0	Y	
34	9	9	10	RB1	AN10	C12IN3-								INT1	Y	
35	10	10	11	RB2	AN8		CTED1							INT2	Y	
36	11	11	12	RB3	AN9	C12IN2-	CTED2			CCP2 P2A[1]					Y	
37	12	14	14	RB4	AN11								T5G	IOC	Y	
38	13	15	15	RB5	AN13					CCP3 P3A[3]			T1G T3CKI[2]	IOC	Y	
39	14	16	16	RB6										IOC	Y	PGC
40	15	17	17	RB7										IOC	Y	PGD
15	30	32	34	RC0						P2B[4]			SOSCO T1CKI T3CKI[2] T3G			
16	31	35	35	RC1						CCP2[1] P2A			SOSCI			
17	32	36	36	RC2	AN14		CTPLS			CCP1 P1A			T5CKI			
18	33	37	37	RC3	AN15							SCK1 SCL1				
23	38	42	42	RC4	AN16							SDI1 SDA1				
24	39	43	43	RC5	AN17							SDO1				
25	40	44	44	RC6	AN18						TX1 CK1					
26	1	1	1	RC7	AN19						RX1 DT1					
19	34	38	38	RD0	AN20							SCK2 SCL2				
20	35	39	39	RD1	AN21					CCP4		SDI2 SDA2				
21	36	40	40	RD2	AN22					P2B[4]						
22	37	41	41	RD3	AN23					P2C		$\overline{SS2}$				
27	2	2	2	RD4	AN24					P2D		SD02				
28	3	3	3	RD5	AN25					P1B						
29	4	4	4	RD6	AN26					P1C	TX2 CK2					
30	5	5	5	RD7	AN27					P1D	RX2 DT2					
8	23	25	25	RE0	AN5					CCP3 P3A[3]						

Note 1: CCP2 multiplexed in fuses.
2: T3CKI multiplexed in fuses.
3: CCP3/P3A multiplexed in fuses.
4: P2B multiplexed in fuses.

TABLE 3: PIC18(L)F4XK22 PIN SUMMARY (CONTINUED)

40-PDIP	40-UQFN	44-TQFP	44-QFN	I/O	Analog	Comparator	CTMU	SR Latch	Reference	(E)CCP	EUSART	MSSP	Timers	Interrupts	Pull-up	Basic
9	24	26	26	RE1	AN6					P3B						
10	25	27	27	RE2	AN7					CCP5						
1	16	18	18	RE3											Y	$\overline{MCLR}$ V_{PP}
11, 32	7, 26	7, 28	7,8 28, 29	V_{DD}												V_{DD}
12, 31	6, 27	6, 29	6, 30, 31	V_{SS}												V_{SS}
—	—	12, 13 33, 34	13	NC												

Note 1: CCP2 multiplexed in fuses.
2: T3CKI multiplexed in fuses.
3: CCP3/P3A multiplexed in fuses.
4: P2B multiplexed in fuses.

22.0 DIGITAL-TO-ANALOG CONVERTER (DAC) MODULE

The Digital-to-Analog Converter supplies a variable voltage reference, ratiometric with the input source, with 32 selectable output levels.

The input of the DAC can be connected to:

- External VREF pins
- VDD supply voltage
- FVR (Fixed Voltage Reference)

The output of the DAC can be configured to supply a reference voltage to the following:

- Comparator positive input
- ADC input channel
- DACOUT pin

The Digital-to-Analog Converter (DAC) can be enabled by setting the DACEN bit of the VREFCON1 register.

22.1 Output Voltage Selection

The DAC has 32 voltage level ranges. The 32 levels are set with the DACR<4:0> bits of the VREFCON2 register.

The DAC output voltage is determined by the following equations:

EQUATION 22-1: DAC OUTPUT VOLTAGE

$$V_{OUT} = \left((V_{SRC+} - V_{SRC-}) \times \frac{DACR<4:0>}{2^5}\right) + V_{SRC-}$$

$$V_{SRC+} = V_{DD},\ V_{REF+}\ or\ FVR1$$

$$V_{SRC-} = V_{SS}\ or\ V_{REF-}$$

22.2 Ratiometric Output Level

The DAC output value is derived using a resistor ladder with each end of the ladder tied to a positive and negative voltage reference input source. If the voltage of either input source fluctuates, a similar fluctuation will result in the DAC output value.

The value of the individual resistors within the ladder can be found in **Section 27.0 "Electrical Specifications"**.

22.3 Low-Power Voltage State

In order for the DAC module to consume the least amount of power, one of the two voltage reference input sources to the resistor ladder must be disconnected. Either the positive voltage source, (VSRC+), or the negative voltage source, (VSRC-) can be disabled.

The negative voltage source is disabled by setting the DACLPS bit in the VREFCON1 register. Clearing the DACLPS bit in the VREFCON1 register disables the positive voltage source.

22.4 Output Clamped to Positive Voltage Source

The DAC output voltage can be set to VSRC+ with the least amount of power consumption by performing the following:

- Clearing the DACEN bit in the VREFCON1 register.
- Setting the DACLPS bit in the VREFCON1 register.
- Configuring the DACPSS bits to the proper positive source.
- Configuring the DACRx bits to '11111' in the VREFCON2 register.

This is also the method used to output the voltage level from the FVR to an output pin. See **Section 22.6 "DAC Voltage Reference Output"** for more information.

22.5 Output Clamped to Negative Voltage Source

The DAC output voltage can be set to VSRC- with the least amount of power consumption by performing the following:

- Clearing the DACEN bit in the VREFCON1 register.
- Clearing the DACLPS bit in the VREFCON1 register.
- Configuring the DACPSS bits to the proper negative source.
- Configuring the DACRx bits to '00000' in the VREFCON2 register.

This allows the comparator to detect a zero-crossing while not consuming additional current through the DAC module.

22.6 DAC Voltage Reference Output

The DAC can be output to the DACOUT pin by setting the DACOE bit of the VREFCON1 register to '1'. Selecting the DAC reference voltage for output on the DACOUT pin automatically overrides the digital output buffer and digital input threshold detector functions of that pin. Reading the DACOUT pin when it has been configured for DAC reference voltage output will always return a '0'.

Due to the limited current drive capability, a buffer must be used on the DAC voltage reference output for external connections to DACOUT. Figure 22-2 shows an example buffering technique.

FIGURE 22-1: DIGITAL-TO-ANALOG CONVERTER BLOCK DIAGRAM

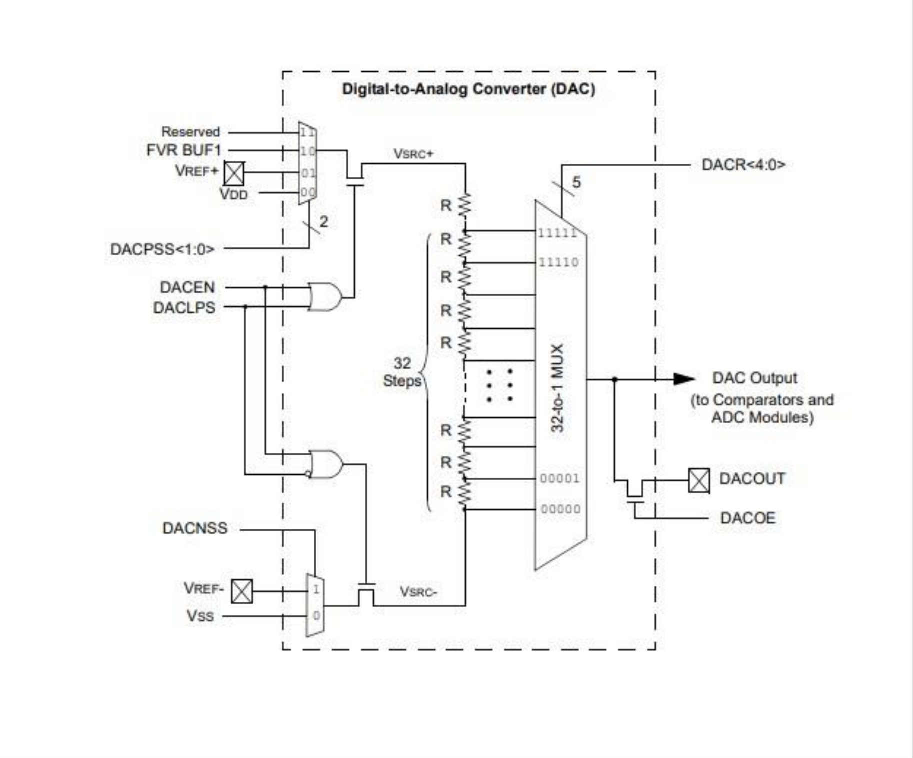
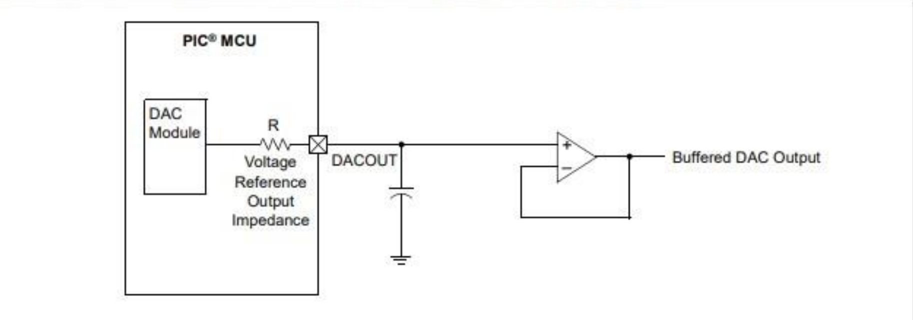


FIGURE 22-2: VOLTAGE REFERENCE OUTPUT BUFFER EXAMPLE



22.7 Operation During Sleep

When the device wakes up from Sleep through an interrupt or a Watchdog Timer time-out, the contents of the VREFCON1 register are not affected. To minimize current consumption in Sleep mode, the voltage reference should be disabled.

22.8 Effects of a Reset

A device Reset affects the following:

- DAC is disabled
- DAC output voltage is removed from the DACOUT pin
- The DACR<4:0> range select bits are cleared

22.9 Register Definitions: DAC Control

REGISTER 22-1: VREFCON1: VOLTAGE REFERENCE CONTROL REGISTER 0

R/W-0	R/W-0	R/W-0	U-0	R/W-0	R/W-0	U-0	R/W-0
DACEN	DACLPS	DACOE	—	DACPSS<1:0>		—	DACNSS
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

bit 7 **DACEN:** DAC Enable bit
1 = DAC is enabled
0 = DAC is disabled

bit 6 **DACLPS:** DAC Low-Power Voltage Source Select bit
1 = DAC Positive reference source selected
0 = DAC Negative reference source selected

bit 5 **DACOE:** DAC Voltage Output Enable bit
1 = DAC voltage level is also an output on the DACOUT pin
0 = DAC voltage level is disconnected from the DACOUT pin

bit 4 **Unimplemented:** Read as '0'

bit 3-2 **DACPSS<1:0>:** DAC Positive Source Select bits
00 = VDD
01 = VREF+
10 = FVR BUF1 output
11 = Reserved, do not use

bit 1 **Unimplemented:** Read as '0'

bit 0 **DACNSS:** DAC Negative Source Select bits
1 = VREF-
0 = VSS

REGISTER 22-2: VREFCON2: VOLTAGE REFERENCE CONTROL REGISTER 1

U-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	—	DACR<4:0>				
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

bit 7-5 **Unimplemented:** Read as '0'

bit 4-0 **DACR<4:0>:** DAC Voltage Output Select bits
$V_{OUT} = ((V_{SRC+}) - (V_{SRC-}))*(DACR<4:0>/(2^5)) + V_{SRC-}$

TABLE 22-1: REGISTERS ASSOCIATED WITH DAC MODULE

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
VREFCON0	FVREN	FVRST	FVRS<1:0>		—	—	—	—	332
VREFCON1	DACEN	DACLPS	DACOE	—	DACPSS<1:0>		—	DACNSS	335
VREFCON2	—	—	—	DACR<4:0>					336

Legend: — = Unimplemented locations, read as '0'. Shaded bits are not used by the DAC module.

National Semiconductor

January 2000

LM3914 Dot/Bar Display Driver

General Description

The LM3914 is a monolithic integrated circuit that senses analog voltage levels and drives 10 LEDs, providing a linear analog display. A single pin changes the display from a moving dot to a bar graph. Current drive to the LEDs is regulated and programmable, eliminating the need for resistors. This feature is one that allows operation of the whole system from less than 3V.

The circuit contains its own adjustable reference and accurate 10-step voltage divider. The low-bias-current input buffer accepts signals down to ground, or V$^-$, yet needs no protection against inputs of 35V above or below ground. The buffer drives 10 individual comparators referenced to the precision divider. Indication non-linearity can thus be held typically to ½%, even over a wide temperature range.

Versatility was designed into the LM3914 so that controller, visual alarm, and expanded scale functions are easily added on to the display system. The circuit can drive LEDs of many colors, or low-current incandescent lamps. Many LM3914s can be "chained" to form displays of 20 to over 100 segments. Both ends of the voltage divider are externally available so that 2 drivers can be made into a zero-center meter.

The LM3914 is very easy to apply as an analog meter circuit. A 1.2V full-scale meter requires only 1 resistor and a single 3V to 15V supply in addition to the 10 display LEDs. If the 1 resistor is a pot, it becomes the LED brightness control. The simplified block diagram illustrates this extremely simple external circuitry.

When in the dot mode, there is a small amount of overlap or "fade" (about 1 mV) between segments. This assures that at no time will all LEDs be "OFF", and thus any ambiguous display is avoided. Various novel displays are possible.

Much of the display flexibility derives from the fact that all outputs are individual, DC regulated currents. Various effects can be achieved by modulating these currents. The individual outputs can drive a transistor as well as a LED at the same time, so controller functions including "staging" control can be performed. The LM3914 can also act as a programmer, or sequencer.

The LM3914 is rated for operation from 0˚C to +70˚C. The LM3914N-1 is available in an 18-lead molded (N) package.

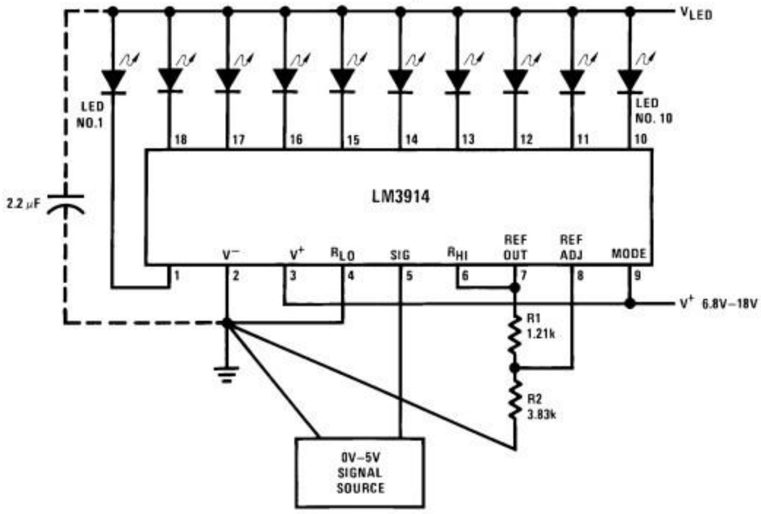
The following typical application illustrates adjusting of the reference to a desired value, and proper grounding for accurate operation, and avoiding oscillations.

Features

- Drives LEDs, LCDs or vacuum fluorescents
- Bar or dot display mode externally selectable by user
- Expandable to displays of 100 steps
- Internal voltage reference from 1.2V to 12V
- Operates with single supply of less than 3V
- Inputs operate down to ground
- Output current programmable from 2 mA to 30 mA
- No multiplex switching or interaction between outputs
- Input withstands ±35V without damage or false outputs
- LED driver outputs are current regulated, open-collectors
- Outputs can interface with TTL or CMOS logic
- The internal 10-step divider is floating and can be referenced to a wide range of voltages

Typical Applications

0V to 5V Bar Graph Meter



$$\text{Ref Out V} = 1.25\left(1 + \frac{R2}{R1}\right)$$

$$I_{LED} \cong \frac{12.5}{R1}$$

Note: Grounding method is typical of *all* uses. The 2.2 µF tantalum or 10 µF aluminum electrolytic capacitor is needed if leads to the LED supply are 6" or longer.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Power Dissipation (Note 6)	
Molded DIP (N)	1365 mW
Supply Voltage	25V
Voltage on Output Drivers	25V
Input Signal Overvoltage (Note 4)	±35V
Divider Voltage	−100 mV to V+
Reference Load Current	10 mA
Storage Temperature Range	−55˚C to +150˚C
Soldering Information	
Dual-In-Line Package	
Soldering (10 seconds)	260˚C
Plastic Chip Carrier Package	
Vapor Phase (60 seconds)	215˚C
Infrared (15 seconds)	220˚C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

Electrical Characteristics (Notes 2, 4)

Parameter	Conditions (Note 2)		Min	Typ	Max	Units
COMPARATOR						
Offset Voltage, Buffer and First Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA			3	10	mV
Offset Voltage, Buffer and Any Other Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA			3	15	mV
Gain ($\Delta I_{LED}/\Delta V_{IN}$)	$I_{L(REF)} = 2$ mA, $I_{LED} = 10$ mA		3	8		mA/mV
Input Bias Current (at Pin 5)	$0V \le V_{IN} \le V^+ - 1.5V$			25	100	nA
Input Signal Overvoltage	No Change in Display		−35		35	V
VOLTAGE-DIVIDER						
Divider Resistance	Total, Pin 6 to 4		8	12	17	kΩ
Accuracy	(Note 3)			0.5	2	%
VOLTAGE REFERENCE						
Output Voltage	$0.1\text{ mA} \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$		1.2	1.28	1.34	V
Line Regulation	$3V \le V^+ \le 18V$			0.01	0.03	%/V
Load Regulation	$0.1\text{ mA} \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$			0.4	2	%
Output Voltage Change with Temperature	$0˚C \le T_A \le +70˚C$, $I_{L(REF)} = 1$ mA, $V^+ = 5V$			1		%
Adjust Pin Current				75	120	µA
OUTPUT DRIVERS						
LED Current	$V^+ = V_{LED} = 5V$, $I_{L(REF)} = 1$ mA		7	10	13	mA
LED Current Difference (Between Largest and Smallest LED Currents)	$V_{LED} = 5V$	$I_{LED} = 2$ mA		0.12	0.4	mA
		$I_{LED} = 20$ mA		1.2	3	
LED Current Regulation	$2V \le V_{LED} \le 17V$	$I_{LED} = 2$ mA		0.1	0.25	mA
		$I_{LED} = 20$ mA		1	3	
Dropout Voltage	$I_{LED(ON)} = 20$ mA, $V_{LED} = 5V$, $\Delta I_{LED} = 2$ mA				1.5	V
Saturation Voltage	$I_{LED} = 2.0$ mA, $I_{L(REF)} = 0.4$ mA			0.15	0.4	V
Output Leakage, Each Collector	(Bar Mode) (Note 5)			0.1	10	µA
Output Leakage	(Dot Mode) (Note 5)	Pins 10–18		0.1	10	µA
		Pin 1	60	150	450	µA
SUPPLY CURRENT						
Standby Supply Current (All Outputs Off)	$V^+ = 5V$, $I_{L(REF)} = 0.2$ mA			2.4	4.2	mA
	$V^+ = 20V$, $I_{L(REF)} = 1.0$ mA			6.1	9.2	mA

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Electrical Characteristics (Notes 2, 4) (Continued)

Note 2: Unless otherwise stated, all specifications apply with the following conditions:

$3\ V_{DC} \le V^+ \le 20\ V_{DC}$ $V_{REF}, V_{RHI}, V_{RLO} \le (V^+ - 1.5V)$

$3\ V_{DC} \le V_{LED} \le V^+$ $0V \le V_{IN} \le V^+ - 1.5V$

$-0.015V \le V_{RLO} \le 12\ V_{DC}$ $T_A = +25°C$, $I_{L(REF)} = 0.2$ mA, $V_{LED} = 3.0V$, pin 9 connected to pin 3 (Bar Mode).

$-0.015V \le V_{RHI} \le 12\ V_{DC}$

For higher power dissipations, pulse testing is used.

Note 3: Accuracy is measured referred to $+10.000\ V_{DC}$ at pin 6, with $0.000\ V_{DC}$ at pin 4. At lower full-scale voltages, buffer and comparator offset voltage may add significant error.

Note 4: Pin 5 input current must be limited to ±3 mA. The addition of a 39k resistor in series with pin 5 allows ±100V signals without damage.

Note 5: Bar mode results when pin 9 is within 20 mV of V^+. Dot mode results when pin 9 is pulled at least 200 mV below V^+ or left open circuit. LED No. 10 (pin 10 output current) is disabled if pin 9 is pulled 0.9V or more below V_{LED}.

Note 6: The maximum junction temperature of the LM3914 is 100°C. Devices must be derated for operation at elevated temperatures. Junction to ambient thermal resistance is 55°C/W for the molded DIP (N package).

Definition of Terms

Accuracy: The difference between the observed threshold voltage and the ideal threshold voltage for each comparator. Specified and tested with 10V across the internal voltage divider so that resistor ratio matching error predominates over comparator offset voltage.

Adjust Pin Current: Current flowing out of the reference adjust pin when the reference amplifier is in the linear region.

Comparator Gain: The ratio of the change in output current (I_{LED}) to the change in input voltage (V_{IN}) required to produce it for a comparator in the linear region.

Dropout Voltage: The voltage measured at the current source outputs required to make the output current fall by 10%.

Input Bias Current: Current flowing out of the signal input when the input buffer is in the linear region.

LED Current Regulation: The change in output current over the specified range of LED supply voltage (V_{LED}) as measured at the current source outputs. As the forward voltage of an LED does not change significantly with a small change in forward current, this is equivalent to changing the voltage at the LED anodes by the same amount.

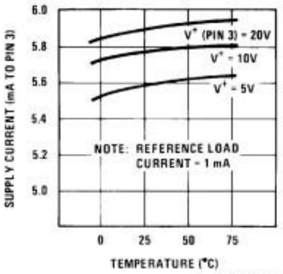
Line Regulation: The average change in reference output voltage over the specified range of supply voltage (V^+).

Load Regulation: The change in reference output voltage (V_{REF}) over the specified range of load current ($I_{L(REF)}$).

Offset Voltage: The differential input voltage which must be applied to each comparator to bias the output in the linear region. Most significant error when the voltage across the internal voltage divider is small. Specified and tested with pin 6 voltage (V_{RHI}) equal to pin 4 voltage (V_{RLO}).

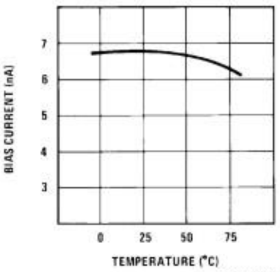
Typical Performance Characteristics

Supply Current vs Temperature



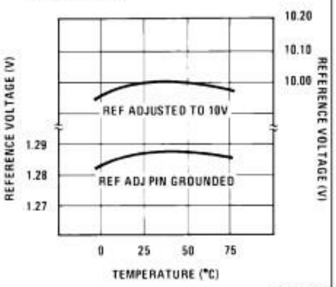
DS007970-2

Operating Input Bias Current vs Temperature



DS007970-20

Reference Voltage vs Temperature



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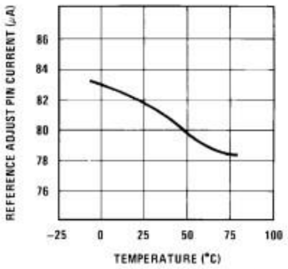
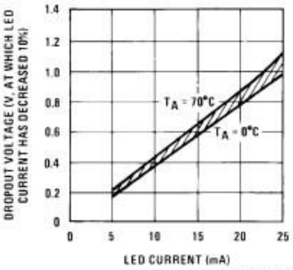
Typical Performance Characteristics (Continued)

Reference Adjust Pin Current vs Temperature



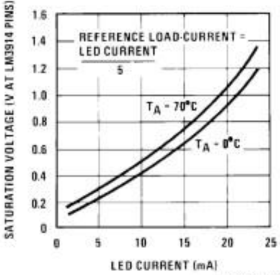
DS007970-22

LED Current-Regulation Dropout



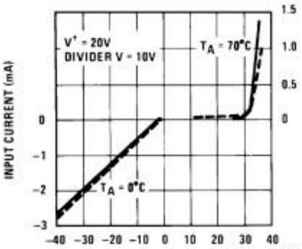
DS007970-23

LED Driver Saturation Voltage



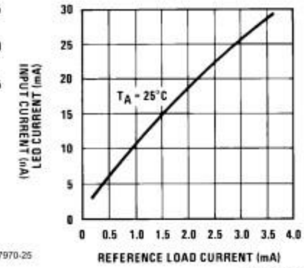
DS007970-24

Input Current Beyond Signal Range (Pin 5)



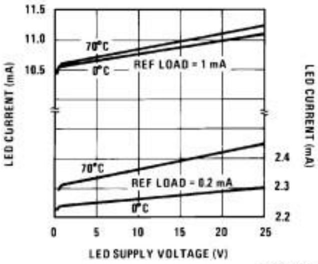
DS007970-25

LED Current vs Reference Loading



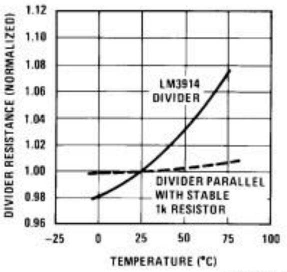
DS007970-26

LED Driver Current Regulation



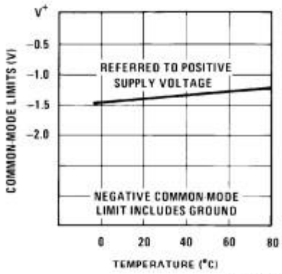
DS007970-27

Total Divider Resistance vs Temperature



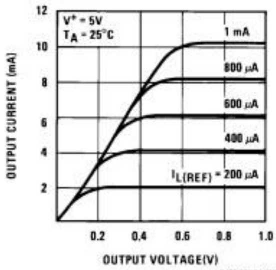
DS007970-28

Common-Mode Limits



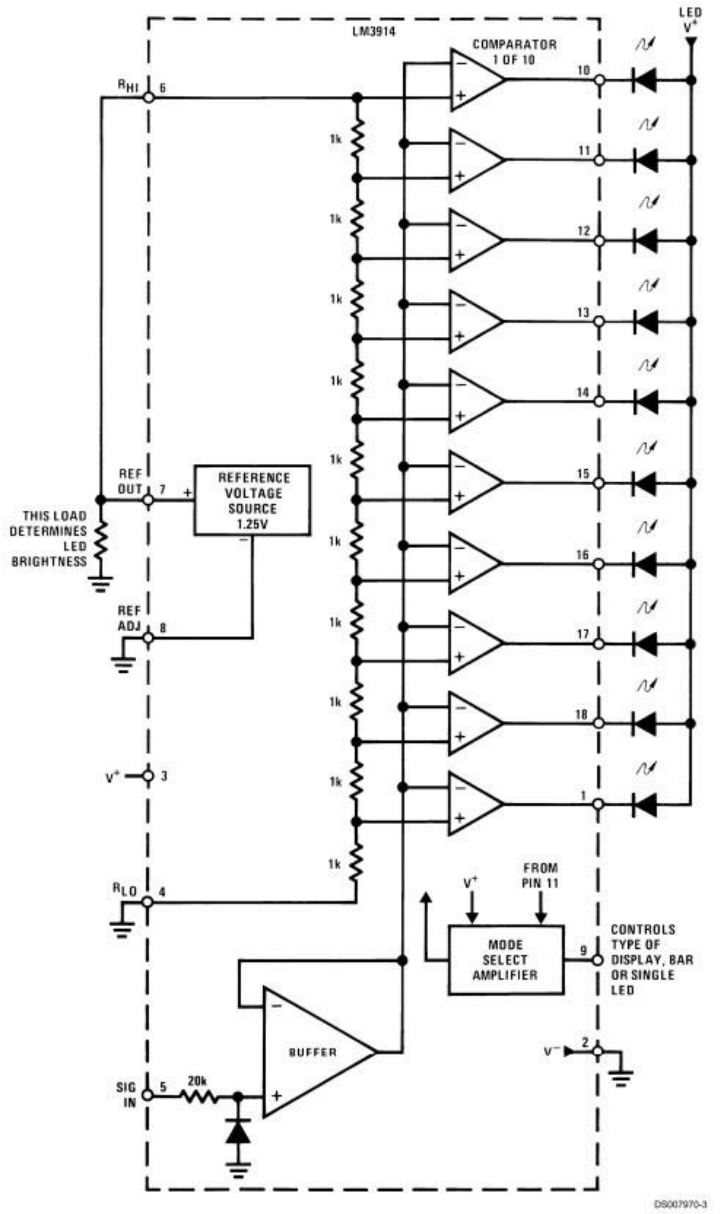
DS007970-29

Output Characteristics



DS007970-30

Block Diagram (Showing Simplest Application)



Functional Description

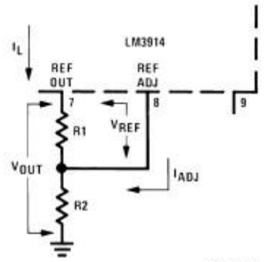
The simplifed LM3914 block diagram is to give the general idea of the circuit's operation. A high input impedance buffer operates with signals from ground to 12V, and is protected against reverse and overvoltage signals. The signal is then applied to a series of 10 comparators; each of which is biased to a different comparison level by the resistor string.

In the example illustrated, the resistor string is connected to the internal 1.25V reference voltage. In this case, for each 125 mV that the input signal increases, a comparator will switch on another indicating LED. This resistor divider can be connected between any 2 voltages, providing that they are 1.5V below V^+ and no less than V^-. If an expanded scale meter display is desired, the total divider voltage can be as little as 200 mV. Expanded-scale meter displays are more accurate and the segments light uniformly only if bar mode is used. At 50 mV or more per step, dot mode is usable.

INTERNAL VOLTAGE REFERENCE

The reference is designed to be adjustable and develops a nominal 1.25V between the REF OUT (pin 7) and REF ADJ (pin 8) terminals. The reference voltage is impressed across program resistor R1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R2 giving an output voltage of:

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) + I_{ADJ} R_2$$



DS007970-4

Since the 120 µA current (max) from the adjust terminal represents an error term, the reference was designed to minimize changes of this current with V^+ and load changes.

CURRENT PROGRAMMING

A feature not completely illustrated by the block diagram is the LED brightness control. The current drawn out of the reference voltage pin (pin 7) determines LED current. Approximately 10 times this current will be drawn through each lighted LED, and this current will be relatively constant despite supply voltage and temperature changes. Current drawn by the internal 10-resistor divider, as well as by the external current and voltage-setting divider should be included in calculating LED drive current. The ability to modulate LED brightness with time, or in proportion to input voltage and other signals can lead to a number of novel displays or ways of indicating input overvoltages, alarms, etc.

MODE PIN USE

Pin 9, the Mode Select input controls chaining of multiple LM3914s, and controls bar or dot mode operation. The following tabulation shows the basic ways of using this input. Other more complex uses will be illustrated in the applications.

Bar Graph Display: Wire Mode Select (pin 9) *directly* to pin 3 (V^+ pin).

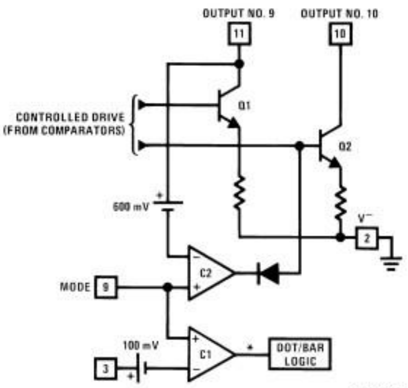
Dot Display, Single LM3914 Driver: Leave the Mode Select pin open circuit.

Dot Display, 20 or More LEDs: Connect pin 9 of the *first* driver in the series (i.e., the one with the lowest input voltage comparison points) to pin 1 of the next higher LM3914 driver. Continue connecting pin 9 of lower input drivers to pin 1 of higher input drivers for 30, 40, or more LED displays. The last LM3914 driver in the chain will have pin 9 wired to pin 11. All previous drivers should have a 20k resistor in parallel with LED No. 9 (pin 11 to V_{LED}).

Mode Pin Functional Description

This pin actually performs two functions. Refer to the simplified block diagram below.

Block Diagram of Mode Pin Description



DS007970-5

*High for bar

DOT OR BAR MODE SELECTION

The voltage at pin 9 is sensed by comparator C1, nominally referenced to (V^+ − 100 mV). The chip is in bar mode when pin 9 is above this level; otherwise it's in dot mode. The comparator is designed so that pin 9 can be left open circuit for dot mode.

Taking into account comparator gain and variation in the 100 mV reference level, pin 9 should be no more than 20 mV below V^+ for bar mode and more than 200 mV below V^+ (or open circuit) for dot mode. In most applications, pin 9 is either open (dot mode) or tied to V^+ (bar mode). In bar mode, pin 9 should be connected directly to pin 3. Large currents drawn from the power supply (LED current, for example) should not share this path so that large IR drops are avoided.

DOT MODE CARRY

In order for the display to make sense when multiple LM3914s are cascaded in dot mode, special circuitry has been included to shut off LED No. 10 of the first device when

Mode Pin Functional Description

(Continued)

LED No. 1 of the second device comes on. The connection for cascading in dot mode has already been described and is depicted below.

As long as the input signal voltage is below the threshold of the second LM3914, LED No. 11 is off. Pin 9 of LM3914 No. 1 thus sees effectively an open circuit so the chip is in dot mode. As soon as the input voltage reaches the threshold of LED No. 11, pin 9 of LM3914 No. 1 is pulled an LED drop (1.5V or more) below V_{LED}. This condition is sensed by comparator C2, referenced 600 mV below V_{LED}. This forces the output of C2 low, which shuts off output transistor Q2, extinguishing LED No. 10.

V_{LED} is sensed via the 20k resistor connected to pin 11. The very small current (less than 100 µA) that is diverted from LED No. 9 does not noticeably affect its intensity.

An auxiliary current source at pin 1 keeps at least 100 µA flowing through LED No. 11 even if the input voltage rises high enough to extinguish the LED. This ensures that pin 9 of LM3914 No. 1 is held low enough to force LED No. 10 off when *any* higher LED is illuminated. While 100 µA does not normally produce significant LED illumination, it may be noticeable when using high-efficiency LEDs in a dark environment. If this is bothersome, the simple cure is to shunt LED No. 11 with a 10k resistor. The 1V IR drop is more than the 900 mV worst case required to hold off LED No. 10 yet small enough that LED No. 11 does not conduct significantly.

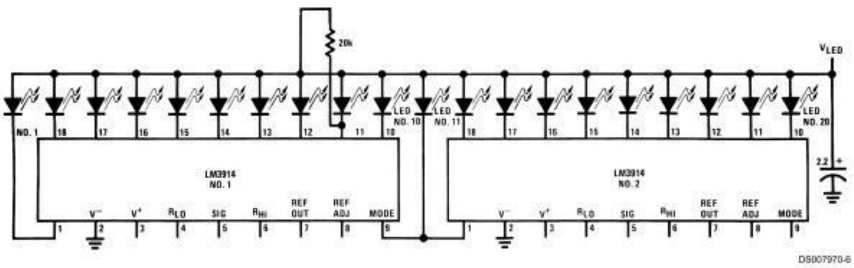
OTHER DEVICE CHARACTERISTICS

The LM3914 is relatively low-powered itself, and since any number of LEDs can be powered from about 3V, it is a very efficient display driver. Typical standby supply current (all LEDs OFF) is 1.6 mA (2.5 mA max). However, any reference loading adds 4 times that current drain to the V+ (pin 3) supply input. For example, an LM3914 with a 1 mA reference pin load (1.3k), would supply almost 10 mA to every LED while drawing only 10 mA from its V+ pin supply. At full-scale, the IC is typically drawing less than 10% of the current supplied to the display.

The display driver does not have built-in hysteresis so that the display does not jump instantly from one LED to the next. Under rapidly changing signal conditions, this cuts down high frequency noise and often an annoying flicker. An "overlap" is built in so that at no time between segments are all LEDs completely OFF in the dot mode. Generally 1 LED fades in while the other fades out over a mV or more of range (Note 3). The change may be much more rapid between LED No. 10 of one device and LED No. 1 of a *second* device "chained" to the first.

The LM3914 features individually current regulated LED driver transistors. Further internal circuitry detects when any driver transistor goes into saturation, and prevents other circuitry from drawing excess current. This results in the ability of the LM3914 to drive and regulate LEDs powered from a pulsating DC power source, i.e., largely unfiltered. (Due to possible oscillations at low voltages a nominal bypass capacitor consisting of a 2.2 µF solid tantalum connected from the pulsating LED supply to pin 2 of the LM3914 is recommended.) This ability to operate with low or fluctuating voltages also allows the display driver to interface with logic circuitry, opto-coupled solid-state relays, and low-current incandescent lamps.

Cascading LM3914s in Dot Mode



4

Kingbright

10 SEGMENT BAR GRAPH ARRAY

Part Number: DC10SRWA   Super Bright Red

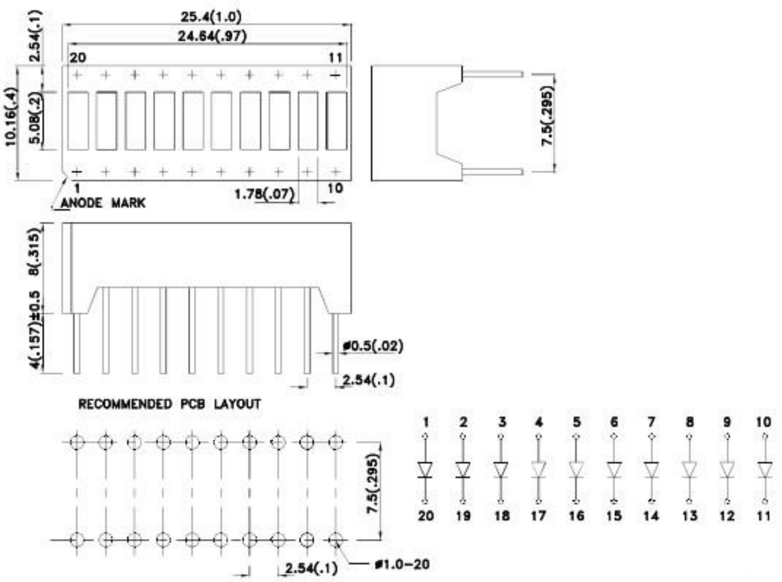
Features

- Suitable for level indicators.
- Low current operation.
- Excellent on/off contrast.
- End stackable.
- Mechanically rugged.
- Standard : gray face, white segment.
- RoHS compliant.

Description

The Super Bright Red source color devices are made with Gallium Aluminum Arsenide Red Light Emitting Diode.

Package Dimensions& Internal Circuit Diagram



Notes:
1. All dimensions are in millimeters (inches), Tolerance is ±0.25(0.01")unless otherwise noted.
2. The specifications, characteristics and technical data described in the datasheet are subject to change without prior notice.

SPEC NO: DSAD1427	REV NO: V.9	DATE: MAR/24/2011	PAGE: 1 OF 6
APPROVED: WYNEC	CHECKED: Joe Lee	DRAWN: J.Yu	ERP: 1331000048

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Selection Guide

Part No.	Dice	Lens Type	Iv (ucd) [1] @ 10mA		Description
			Min.	Typ.	
DC10SRWA	Super Bright Red (GaAlAs)	White Diffused	14000	30000	10 Segments Bar graph-Display

Note:
1. Luminous intensity/ luminous Flux: +/-15%.

Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λpeak	Peak Wavelength	Super Bright Red	660		nm	I_F=20mA
λD [1]	Dominant Wavelength	Super Bright Red	640		nm	I_F=20mA
Δλ1/2	Spectral Line Half-width	Super Bright Red	20		nm	I_F=20mA
C	Capacitance	Super Bright Red	45		pF	V_F=0V;f=1MHz
V_F [2]	Forward Voltage	Super Bright Red	1.85	2.5	V	I_F=20mA
I_R	Reverse Current	Super Bright Red		10	uA	V_R=5V

Notes:
1.Wavelength: +/-1nm.
2. Forward Voltage: +/-0.1V.

Absolute Maximum Ratings at TA=25°C

Parameter	Super Bright Red	Units
Power dissipation	75	mW
DC Forward Current	30	mA
Peak Forward Current [1]	155	mA
Reverse Voltage	5	V
Operating / Storage Temperature	-40°C To +85°C	
Lead Solder Temperature[2]	260°C For 3-5 Seconds	

Notes:
1. 1/10 Duty Cycle, 0.1ms Pulse Width.
2. 2mm below package base.

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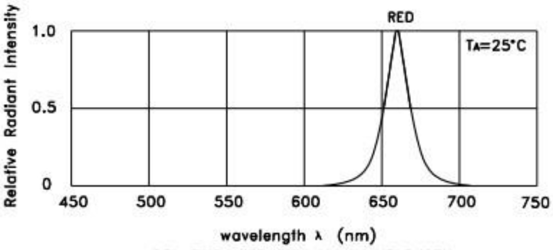
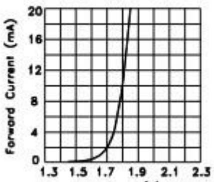
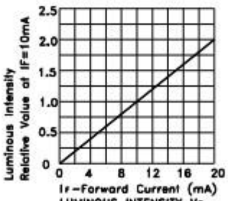


RELATIVE INTENSITY Vs. WAVELENGTH

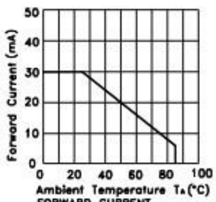
Super Bright Red **DC10SRWA**



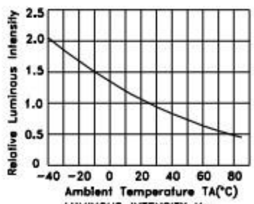
FORWARD CURRENT Vs. FORWARD VOLTAGE



LUMINOUS INTENSITY Vs. FORWARD CURRENT



FORWARD CURRENT DERATING CURVE



LUMINOUS INTENSITY Vs. AMBIENT TEMPERATURE

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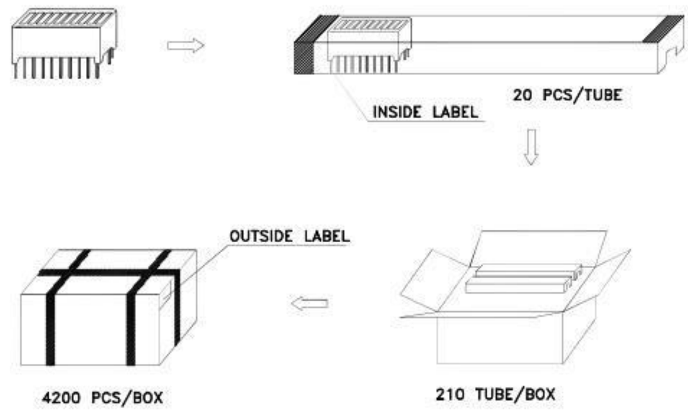
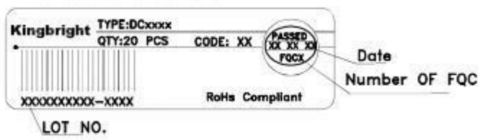
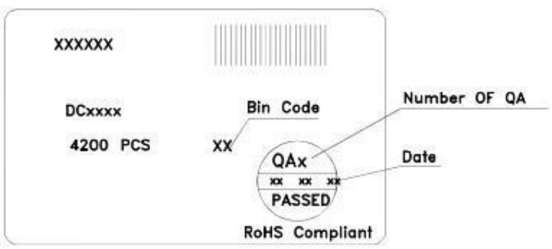
PACKING & LABEL SPECIFICATIONS **DC10SRWA**



Inside Label On IC–tube



Outside Label On Box



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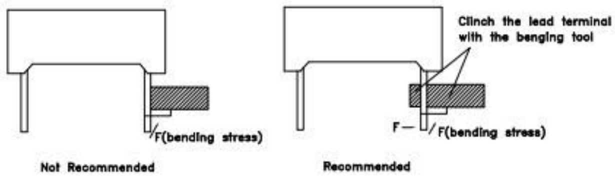
THROUGH HOLE DISPLAY MOUNTING METHOD

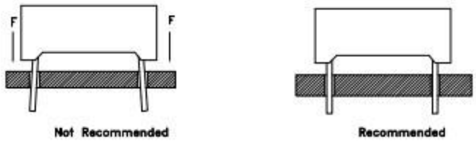
Lead Forming

Do not bend the component leads by hand without proper tools.
The leads should be bent by clinching the upper part of the lead firmly such that the bending force is not exerted on the plastic body.



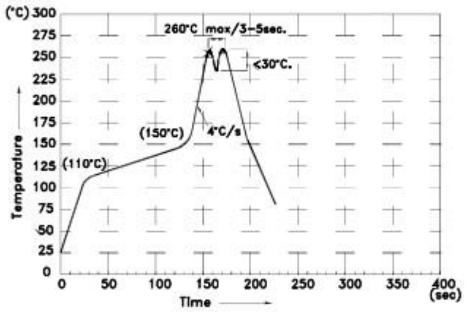
Installation

1. The installation process should not apply stress to the lead terminals.
2. When inserting for assembly, ensure the terminal pitch matches the substrate board's hole pitch to prevent spreading or pinching the lead terminals.



DISPLAY SOLDERING CONDITIONS

Wave Soldering Profile For Lead-free Through-hole LED.



NOTES:
1. Recommend the wave temperature 245°C~260°C.The maximum soldering temperature should be less than 260°C.
2. Do not apply stress on epoxy resins when temperature is over 85°C.
3. The soldering profile apply to the lead free soldering (Sn/Cu/Ag alloy).
4. During wave soldering , the PCB top-surface temperature should be kept below 105°C
5. No more than once.

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Soldering General Notes:

a. Through–hole displays are incompatible with reflow soldering.

b. If components will undergo multiple soldering processes, or other processes where the components may be subjected to intense heat, please check with Kingbright for compatibility.

CLEANING

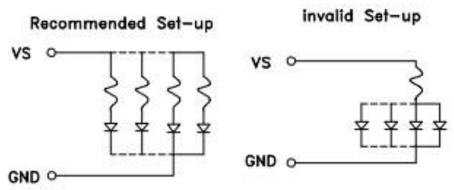
1.Mild "no–clean" fluxes are recommended for use in soldering.

2. If cleaning is required, Kingbright recommends to wash components with water only. Do not use harsh organic solvents for cleaning, because they may damage the plastic parts .And the devices should not be washed for more than one minute.

CIRCUIT DESIGN NOTES

1.Protective current–limiting resistors may be necessary to operate the Displays.

2.LEDs mounted in parallel should each be placed in series with its own current–limiting resistor.



LM016L

- 16 Character x 2 lines
- Built-in control LSI HD44780 type (see page 23)
- +5V single power supply

MECHANICAL DATA (Nominal dimensions)

Module size . . . . 84W x 44H x 12D (max.) mm
Effective display area . . . . 61W x 15.8H mm
Character size (5 x 7 dots) . . . . 2.96W x 4.86H mm
Pitch . . . . 3.55 mm
Dot size . . . . 0.56W x 0.66H mm
Weight . . . . about 25 g

ABSOLUTE MAXIMUM RATINGS

	min.	max.
Power supply for logic ($V_{DD}-V_{SS}$)	0	7.0 V
Power supply for LCD drive ($V_{DD}-V_O$)	0	13.5 V
Input voltage (Vi)	V_{SS}	V_{DD} V
Operating temeprature (Ta)	0	50°C
Storage temperature (Tstg)	−20	70°C

ELECTRICAL CHARACTERISTICS

Ta = 25°C, V_{DD} = 5.0 V ± 0.25 V

Input "high" voltage (Vi_H) . . . . 2.2 V min.
Input "low" voltage (Vi_L) . . . . 0.6 V max.
Output high voltage (V_{OH}) ($-I_{OH}$ = 0.2 mA) . . 2.4 V min.
Output low voltage (V_{OL}) (I_{OL} = 1.2 mA) . . . . 0.4 V max.
Power supply current (I_{DD}) (V_{DD} = 5.0 V) . . 1.0 mA typ.
3.0 mA max.

Power supply for LCD drive (Recommended) ($V_{DD}-V_O$)
Du=1/16
at Ta = 0°C . . . . 4.6 V typ.
at Ta = 25°C . . . . 4.4 V typ.
at Ta = 50°C . . . . 4.2 V typ.

OPTICAL DATA . . . . See page 8

INTERNAL PIN CONNECTION

Pin No.	Symbol	Level	Function	
1	V_{SS}	–	0V	Power supply
2	V_{DD}	–	+5V	
3	V_O	–	–	
4	RS	H/L	L: Instruction code input H: Data input	
5	R/W	H/L	H: Data read (LCD module→MPU) L: Data write (LCD module←MPU)	
6	E	H, H→L	Enable signal	
7	DB0	H/L	Data bus line Note (1), Note (2)	
8	DB1	H/L		
9	DB2	H/L		
10	DB3	H/L		
11	DB4	H/L		
12	DB5	H/L		
13	DB6	H/L		
14	DB7	H/L		

Note:
In the HD44780, the data can be sent in either 4-bit 2-operation or 8-bit 1-operation so that it can interface to both 4 and 8 bit MPU's.

(1) When interface data is 4 bits long, data is transferred using only 4 buses of $DB_4 \sim DB_7$ and $DB_0 \sim DB_3$ are not used. Data transfer between the HD44780 and the MPU completes when 4-bit data is transferred twice. Data of the higher order 4 bits (contents of $DB_4 \sim DB_7$ when interface data is 8 bits long) is transferred first and then lower order 4 bits (contents of $DB_0 \sim DB_3$ when interface data is 8 bits long).

(2) When interface data is 8 bits long, data is transferred using 8 data buses of $DB_0 \sim DB_7$.

Unit: mm

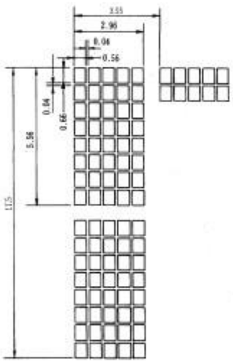


Fig. 1 Display pattern

HITACHI

Unit: mm

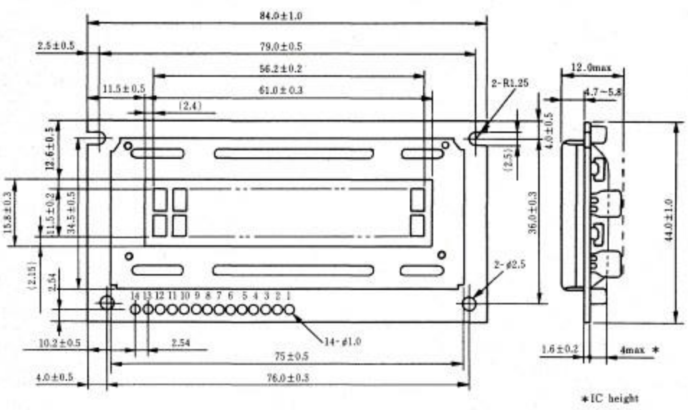


Fig. 2 External dimensions

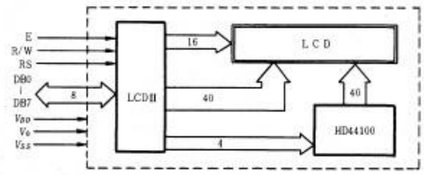


Fig. 3 Block diagram

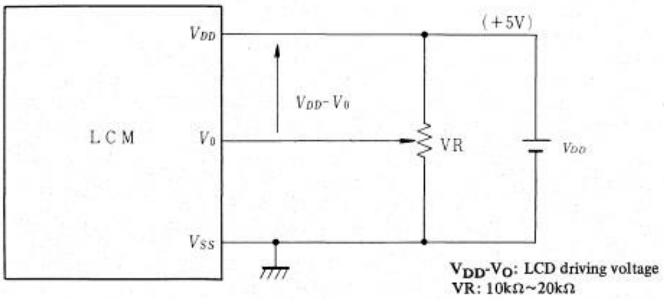


Fig. 4 Power supply

HITACHI

TIMING CHARACTERISTICS

Item	Symbol	Test condition	min.	typ.	max.	Unit
Enable cycle time	t_{cyc}	Fig. 5, Fig. 6	1.0	–	–	μs
Enable pulse width	P_{WEH}	Fig. 5, Fig. 6	450	–	–	ns
Enable rise/fall time	t_{Er}, t_{Ef}	Fig. 5, Fig. 6	–	–	25	ns
RS, R/W set up time	t_{AS}	Fig. 5, Fig. 6	140	–	–	ns
Data delay time	t_{DDR}	Fig. 6	–	–	320	ns
Data set up time	t_{DSW}	Fig. 5	195	–	–	ns
Hold time	t_H	Fig. 5, Fig. 6	20	–	–	ns

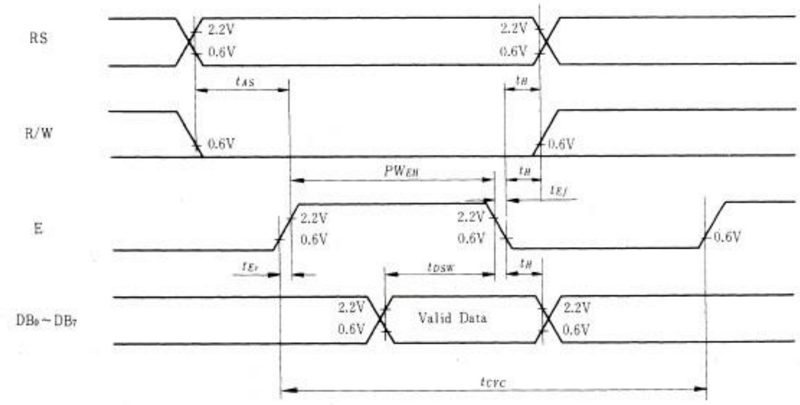


Fig. 5 Interface timing (data write)

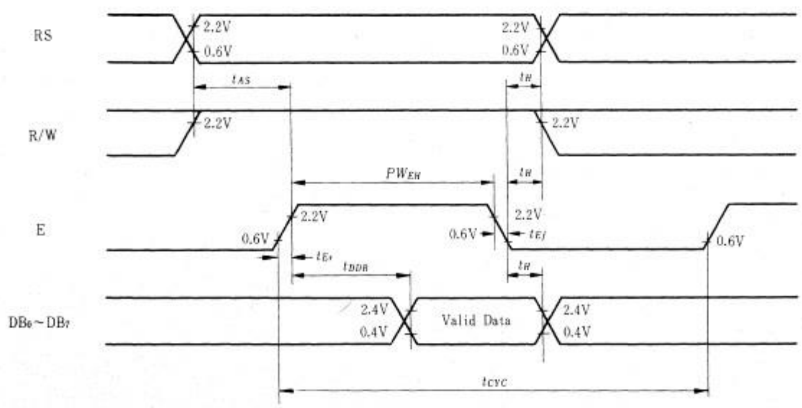


Fig. 6 Interface timing (data read)